Sensitivity of Western and Northern Canada Soils and Geology to Acidic Inputs

Prepared by:

Coordinating Committee on Soils and Geology Sensitivity Mapping

Prepared for:

Western and Northern Canada LRTAP Technical Committee

October 1987

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Alberta ENVIRONMENT

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Northwest Territories Renewable Resources

Canada

Sensitivity of Western and Northern Canada Soils and Geology to Acidic Inputs

by

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ABSTRACT

The Coordinating Committee on Soil and Geology Sensitivity Mapping, Western and Northern Canada Long-Range Transport of Atmospheric Pollutants (LRTAP), coordinated preparation of interpretive maps for each of the western provinces and northern territories. Each province was responsible for mapping their own province. Territories were mapped by federal government agencies. The map entitled: **Potential of Soils and Geology to Reduce Acidity of Atmospheric Deposition** displays ratings of the long-term potential of soils and geology to buffer acidic deposition and modify the effects of drainage water on lakes and streams. The map entitled: **Soil Sensitivity to Acidic Inputs** portrays susceptibility of soils to internal chemical changes which could affect plant growth. The former was prepared for all provinces at a scale of 1:2 000 000 and for the territories at 1:5 000 000. The latter map was not prepared for the Northwest Territories, but at the same scales for all other jurisdictions. This report describes the objectives for the project and the methods used. Accepted rating criteria are defined and differences in data sources and methods are highlighted. The accompanying 1:7 500 000 scale maps were generalized from the maps for each jurisdiction and provide a broad overview for Western and Northern Canada. The report indicates some limitations to use of the maps.

SENSITIVITY OF WESTERN AND NORTHERN CANADA SOILS AND GEOLOGY TO ACIDIC INPUTS

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SENSITIVITY OF WESTERN AND NORTHERN CANADA SOILS AND GEOLOGY TO ACIDIC INPUTS

1. INTRODUCTION

1.1 WHAT IS SENSITIVITY?

Sensitivity is an interpretation which rates likely response of environmental components or receptors to acidic inputs. In this report it refers to interpretations which rate the response of the soils and geology components of terrestrial ecosystems.

Two approaches have been taken in Western and Northern Canada to describing responses of soils and geology. The first, referred to as the potential of soils and geology to reduce acidity, rates the long-term capacity of soils and geology within watersheds to buffer acidic deposition and modify the impacts of drainage water on lakes and streams. The second, referred to as soil sensitivity, rates the susceptibility of soils themselves to changes which could affect plant growth.

1.2 WHAT ARE SENSITIVITY/POTENTIAL MAPS?

To identify the full range of soils and geology in a province, region etc., maps are prepared which delineate similar areas with respect to component soils and/or geology. Legend classes then group similar delineations into mapping units. When information about these mapping units has been interpreted and ratings of sensitivity or potential have been made, sensitivity and potential maps can be prepared. These maps show the geographic extent and distribution of each sensitivity/potential class. Sensitivity and potential classes are formed by grouping all mapping units with a similar sensitivity/potential interpretation.

1.3 WHY PRODUCE SENSITIVITY/POTENTIAL MAPS?

Preparation of sensitivity/potential maps of soils and geology has been a priority of the Western and Northern Canada Long-Range Transport of Air Pollutants (LRTAP) program. Several objectives can be stated:

- to show locations and extent of sensitive areas for comparison with acid deposition information, which would allow identification of control areas,
- to provide a logical basis for future long-term monitoring, and

- to afford an opportunity to review and compile soils and geology information useful to assessing degradation, and to provide a framework for possible further site specific and more detailed investigations of response to acidic inputs.

1.4 ROLE OF THE COORDINATING COMMITTEE ON SOIL AND GEOLOGY SENSITIVITY MAPPING

Initially, the role of the Coordinating Committee was to review and report on the status of sensitivity mapping in Canada (Wotton, 1981). Subsequently, the role of the committee was to ensure reasonable consistency between provinces and territories, and between Western and Eastern Canada in terms of rating criteria and mapping methods (Wiens, 1982, 1983). The Coordinating Committee also had preliminary discussions regarding the implications of the mapping on the selection of target loadings, and on the methods and use of mapping in establishing a long-term monitoring program.

1.5 MAPS PREPARED AS PART OF THIS PROJECT

Interpretive maps were the primary objective of this project. As a prerequisite to meeting this objective, several provinces/territories had to prepare a soils and geology base map at an appropriate scale.

The first interpretative map is entitled: **Potential of Soils and Geology to Reduce Acidity of Atmospheric Deposition.** This map rates the long-term potential of soils and geology to buffer acidic deposition and modify the effects of drainage waters on lakes and streams. It parallels closely a map prepared for Eastern Canada under the Memorandum of Intent on Transboundary Air Pollution (MOI) between Canada and the U.S.A.

The second interpretive map is entitled: **Soil Sensitivity to Acidic Inputs.** This map portrays the distribution of susceptibility of soils to internal chemical changes which could affect plant growth. A similar map was not prepared for Eastern Canada, although specific soil processes were rated and the general criteria for rating in Western and Northern Canada were adapted from some preliminary work done in Eastern Canada.

Accompanying this report are two small scale maps for Western and Northern Canada. These have been prepared by compiling and in some areas generalizing the interpretive maps from each of the respective provinces/territories.

It must be stressed that both interpretative maps for Western and Northern Canada are a first effort. The rating criteria used have drawn heavily on principles of soil chemistry, geology, hydrology, as well as soil fertility and plant nutrition. Supporting investigations to confirm actual changes in soils and geology due to acidic precipitation are limited, as are studies of effects on a wide variety of plant species due to these changes.

2. SENSITIVITY RATING CRITERIA

2.1 BACKGROUND

Various sensitivity ratings and maps have been prepared in Canada. Agriculture Canada (Wang and Coote, 1981; Coote et al., 1981a; Coote et al., 1981b) has developed criteria and prepared sensitivity maps of soils in agricultural areas. The Geological Survey of Canada (Shilts et al., 1981) has prepared bedrock and surficial geology sensitivity maps in Eastern Canada. A report by the Saskatchewan Research Council (Shewchuk et al., 1981) has rated and mapped both geology and soil sensitivity for a portion of Northeastern Alberta and Northern Saskatchewan. The Alberta Research Council (Holowaychuk and Lindsay, 1982) has rated and mapped soil sensitivity of the Sand River area of Alberta.

Cowell et al. (1981) discussed terrestrial sensitivity indices and mapping approaches which have been used in Canada and the United States. They then developed an ecological rating system to evaluate the effects of acid rain on the terrestrial environment of Eastern North America. The sensitivity classification criteria and an evaluating procedure as outlined by Lucas and Cowell (1984) provided the primary framework for preparation of the interpretive maps for Western and Northern Canada entitled: **Potential of Soils and Geology to Reduce Acidity of Atmospheric Deposition.**

Sensitivity rating criteria to reflect potential impacts on plant growth or on forest and agricultural productivity were not developed in Eastern Canada under the MOI process. Wang and Coote (1981) and Coote et al. (1981a) had rated agricultural land on the basis of soil exchangeable base status. Cowell et al. (1981) had proposed a "Forest Productivity Rating" system, but the final MOI report (Bangay and Riordan, 1983) maintained that development of criteria for rating the impact on agricultural and forest productivity required further understanding of cause-effect linkages between acidic deposition and soil mediated impacts on vegetation. Inadequate research was acknowledged by the Coordinating Committee on Soil and Geology Sensitivity Mapping, but a decision was taken to attempt an adaptation of rating criteria and sensitivity mapping for Western and Northern Canada directed at soil changes which could affect plant growth. A starting point for criteria was the sensitivity rating of individual soil processes: base cation loss, acidification, and aluminum solubilization (Bangay and Riordan, 1983).

2.2 DEFINITIONS OF SENSITIVITY - RELATION TO CRITERIA

It is recognized that the definition of sensitivity determines the nature of the sensitivity rating criteria.

Several definitions of sensitivity of terrestrial ecosystems have been proposed. Cowell et al. (1981), and Lucas and Cowell (1984) proposed a multifactor approach to sensitivity assessment combining soil and bedrock information to evaluate the ability of terrestrial ecosystems to reduce acidity of atmospheric deposition. More commonly, however, one component of the terrestrial ecosystem is targeted for sensitivity evaluation and rating. Thus, soil sensitivity, bedrock geology sensitivity, bedrock and surficial geology sensitivity, forest species sensitivity, agricultural crop sensitivity, etc. have been defined and rated accordingly.

Recognizing the concern for potential impacts on both water and vegetation, two definitions were adopted. As used in this report, **potential of soils and geology to reduce acidity** is a measure of the long-term capacity of soils and geology to buffer acidic deposition and modify the effects of drainage waters on aquatic systems. **Soil sensitivity to acidic inputs** is an overall rating of the susceptibility of soils to changes which may be significant to vegetation growth based on inferred changes in the following soil processes: exchangeable base cation loss, soil acidification and pH reductions, and aluminum solubilization.

2.3 FACTORS IMPORTANT TO SENSITIVITY RATING

Literature on the sensitivity to acidic inputs emphasizes different properties and processes for each ecosystem component, in the definition of rating criteria. For soils, the sensitivity to one or more of the following processes has been emphasized:

- exchangeable base cation loss by leaching
- pH reduction
- reduction in organic matter decomposition and mineralization
- increased mineral weathering
- solubilization of trace metals
- solubilization of aluminum.

Attributes of soils or non-soil materials which commonly have been evaluated to interpret sensitivity include:

- cation exchange capacity (CEC)
- degree of base saturation
- soil pH
- organic matter content
- particle-size distribution (texture)
- long-term or short-term buffering capacity
- content of free-carbonates or other weatherable minerals
- sulphate adsorption capacity
- soil depth
- soil drainage
- buffering properties of non-soil materials.

For geology, characteristics of both bedrock and surficial materials must be recognized in rating sensitivity to acidic inputs. Lithology has been used to define and provide criteria for rating bedrock sensitivity (Shilts et al., 1981; Hendrey et al., 1980). It has been demonstrated clearly, however, that the nature of surficial materials overlying bedrock may completely alter the patterns of buffering potential indicated by the map legends which focus on bedrock.

2.4 SENSITIVITY/POTENTIAL RATING CRITERIA

2.4.1 POTENTIAL OF SOILS AND GEOLOGY TO REDUCE ACIDITY OF ATMOSPHERIC DEPOSITION

Classification criteria for rating potential of soils and geology to reduce acidity of acidic deposition were essentially those used in Eastern Canada as part of the MOI process. Table 1 provides a summary of the soil and bedrock attributes considered and the associated sensitivity class limits. Figure 1 portrays the procedure used to evaluate both soils and bedrock geology information for the mapping units of the base maps in order to rate potential. It should be noted that rating was based on only bedrock criteria where

the bedrock was calcareous or where bedrock exposure was dominant in the mapping unit. The rating was based on only soil criteria where soils were deep and not underlain by calcareous bedrock. Where soils were shallow and bedrock was not calcareous, ratings were based on a combination of both bedrock and soil criteria. The underlying assumption in this rating process was that precipitation falling on the land surface percolates downward, contacting soil, surficial materials and bedrock in its passage to aquatic systems. In the evaluation of the Northwest Territories, it was assumed that permafrost in the soil forms an impermeable barrier to such percolation and this was interpreted as a reduced influence of bedrock in terrains with shallow surficial materials.

2.4.2 SOIL SENSITIVITY TO ACIDIC INPUTS

A starting point for development of classification criteria for sensitivity of soils to acidic inputs was a rating scheme for theoretical sensitivities of forest soils to acid deposition (Bangay and Riordan, 1983; Office of Technology Assessment, 1984). Under this scheme sensitivities to base cation loss, to soil acidification, and to aluminum solubilization were rated, based on soil pH, cation exchange capacity, and sulphate adsorption capacity.

A modification of this rating scheme was applied to soils in Western Canada. Refinements of class limits were made for both exchange capacity (from two to three classes) and pH (from three to five classes; six for low CEC) Fessenden, 1985; Holowaychuck et al., 1986). This was done in recognition of the need to: separate unlike soils with respect to CEC; reflect marked increases of aluminum solubilization below pH 5.5 (McKenzie and Nyborg, 1984), and; acknowledge the significance of any bases remaining below pH 4.6 (Mollitor and Raynal, 1982; Staunes, 1980). Because of lack of appropriate information, all soils in Western and Northern Canada were assumed to be non-sulphate adsorbing for purposes of this project. Some workers have concluded that soils in northern glaciated regions of North America are relatively low in the hydrous oxide minerals largely responsible for sulphate adsorption, or adsorb sulphate significantly only at concentrations greater than found *in situ* (Bloom and Grigal, 1985; Fuller et al., 1985).

In addition to rating the three individual soil processes indicated, an overall or combined sensitivity rating was developed. This rating was intended to reflect probable impacts on plant growth and to allow soil sensitivity rating and map preparation. The underlying

Table 1. Terrestrial factors and associated criteria for determining the potential of soils in geology to reduce acidity of atmospheric deposition (modified after Cowell et al. 1981).

TERRESTRIAL FACTORS	POTENTIAL TO REDUCE ACIDITY OF ATMOSPHERIC DEPOSITION		
	HIGH	MODERATE	LOW
Soil Chemistry			
i) Exchangeable Bases Surrogates:	>15 meq/100g	6 to 15 meq/100g	<6 meq/100g
(a) Family Particle Size and pH in water	clayey, >pH 5.0 loamy, >pH 5.5 all calcareous soils	clayey, pH 4.5 to 5.0 loamy, pH 5.0 to 5.5 sandy, >pH 5.5	clayey, <pH 4.5 loamy, <pH 5.0 sandy, <pH 5.5
(b) Texture	clay, silty clay, sandy clay (>35% clay)	silty clay loam, clay loam, sandy clay loam, silt loam, loam (10 to 35% clay)	silt, sandy loam, loamy sand, sand (<10% clay)
(c) Cation Exchange Capacity	>25 meq/100g	10 to 25 meq/100g	<10 meq/100g
ii) SO_4^{2-} Adsorption Capacity	high sulphate adsorption: low organic matter AND high Al_2O_3 and/or Fe_2O_3 + Fe_3O_4 content	———	low sulphate adsorption: high organic matter AND/OR low Al_2O_3 and/or Fe_2O_3 + Fe_3O_4 content
Soil Depth	>1 m	25 cm - 100 cm	<25 cm
Soil Drainage	poor	imperfect to well	rapid
Landform Relief	level	rolling	steep
Vegetation	deciduous	mixed	coniferous
Vegetation Cover	continuous (>60%)	discontinuous to sparse (20 to 60%)	sparse to barren (<20%)
Underlying Material			
i) Parent Material	carbonate bearing	non-carbonate bearing	non-carbonate bearing
ii) Bedrock Material	limestone, dolomite, and metamorphic equivalents, calcareous clastic rocks, carbonate rocks interbedded with non-carbonate rocks	volcanic rocks, shales, greywackes, sandstones, ultramafic rocks, gabbro, mudstone, metaequivalents	granite, granite gneiss, orthoquartzite, syenite

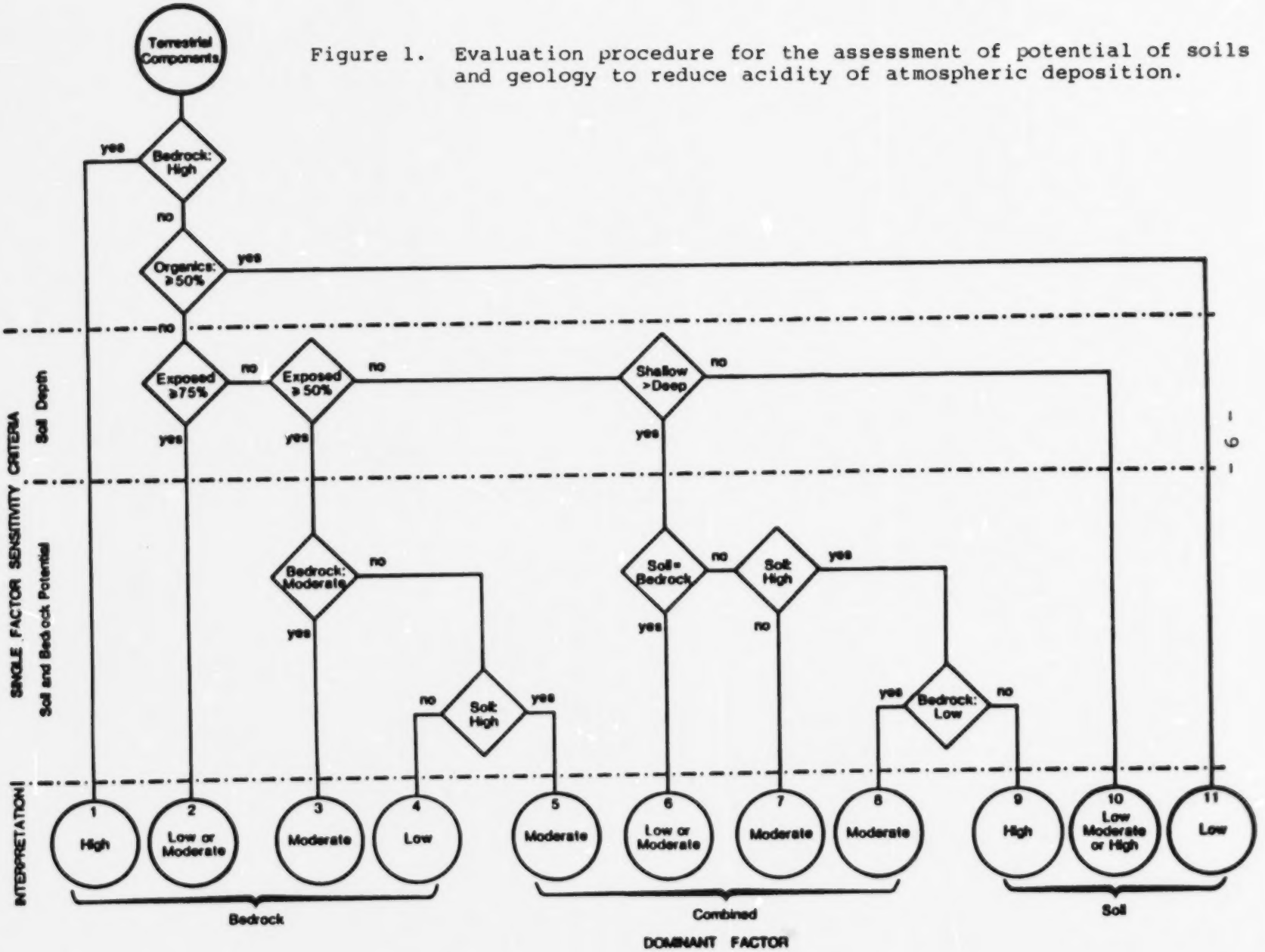


Figure 1. Evaluation procedure for the assessment of potential of soils and geology to reduce acidity of atmospheric deposition.

assumption in an overall sensitivity rating is that information is available or a judgement can be made of the relative effects of changes in the three soil processes. The tentative nature of the rating was recognized, but an attempt at rating was considered useful. Under these conditions it must be recognized that future research or alternative assumptions could affect the extent and distribution of mapped sensitivity classes.

Rating criteria for both the individual soil processes and the overall sensitivity are presented in Table 2. It should be noted that these criteria have been applied to all soils in the Yukon Territory and the western provinces except Alberta. Alberta has applied these criteria to mineral soils, but based rating of three peatland systems on chemical properties of the organic materials and their associated surface waters (Holowaychuck et al., 1986). No rating of soil sensitivity was attempted for the Northwest Territories.

2.5 LIMITATIONS OF SENSITIVITY/POTENTIAL RATINGS

Significant limitations to sensitivity and potential ratings must be acknowledged. It will be evident that a lack of information from research causes uncertainty with respect to items including, but not limited to, the following:

- acidic input vs. response relationships for a range of soil, surficial geology and bedrock properties
- plant growth response to changes in soil properties resulting from acidic inputs
- relative importance of different soil properties and process changes as a result of acidic inputs
- possible non-contact of drainage waters with bedrock due to compact glacial till, compact genetic soil horizons, or presence of permafrost.

Limitations of sensitivity/potential rating criteria are in addition to the limitations resulting from the mapping methodology which are noted below.

TABLE 2: CRITERIA FOR RATING THE SENSITIVITY OF SOILS TO ACIDIC INPUTS[1]

CEC[2] (meq/100g)	pH	Base Loss	Soil Acidification	Aluminum Solubilization	Overall Sensitivity
<6	<4.6	H	L	H	H
	4.6-5.0	H	L	H	H
	5.1-5.5	H	M	H	H
	5.6-6.0	H	H	M	H
	6.1-6.5	H	H	L	H
	>6.5	L	L	L	L
6-15	<4.6	H	L	H	H
	4.6-5.0	M	L	H	M
	5.1-5.5	M	L-M	M	M
	5.6-6.0	M	L-M	L-M	M
	>6.0	L	L	L	L
>15	<4.6	H	L	H	H
	4.6-5.0	M	L	H	M
	5.1-5.5	M	L	M	M
	5.6-6.0	L	L-M	L-M	L
	>6.0	L	L	L	L

[1] Sensitivity Codes: H = High, M = Moderate, L-M = Low to Moderate
L = Low

[2] Cation Exchange Capacity

3. MAPPING METHODOLOGY

3.1 BASE SOILS AND GEOLOGY MAP PREPARATION

A variety of sources of information in each province/territory were used to compile the base soils and geology maps. Intensities of field surveys and scales of mapping, as well as age and purpose of the inventories, are numerous. The following sections highlight significant, and in some cases unique, aspects of the preparation of base maps for each province/territory. Small scale maps are included to indicate relative intensity or scale of inventory source information, and therefore, reliability of mapping. An overall map indicating source information is included with the legend of the accompanying maps.

Soil and geology maps, on which interpretations of sensitivities were based, depict the areal distribution of the various soil and non-soil (e.g. surficial and bedrock geology) characteristics. Dominant materials within the mapping units have provided the primary basis for area delineations but subdominant and minor components usually occur, and in some cases may constitute 20-30% of the area. Although subdominant or minor in extent, these materials may contribute appreciably to the qualities of the map unit delineations. Ratings of response to acidic inputs described later and presented on the maps in this report are for dominant materials, but in a few borderline cases may have been affected by subdominant components. Details of mapping unit descriptions and symbols can be found in reports for each province/territory.

3.1.1 BRITISH COLUMBIA

The soils and geology base map was compiled for the province at a scale of 1:2 000 000. Soil, terrain and bedrock properties that relate to soil acidification and/or influence the potential of the soil to reduce acidity were used as the differentiating criteria for mapping units. These properties were: bedrock type, soil/ material depth, cation exchange capacity, sum of exchangeable bases, pH, and texture. Accessory characteristics included: soil parent material, slope, drainage, soil classification, presence of carbonates, presence of cemented horizons, and presence of thick surface organic accumulations.

A 1:2 000 000 bedrock geology map with four bedrock groupings intended to reflect buffering capacity, was superimposed on an existing 1:2 000 000 scale soils map which defined map units according to soil classification and parent

materials. Minor line adjustments were made to form resulting polygons. Each polygon was characterized in terms of the differentiating and accessory characteristics. For this, all available soil and terrain maps and accompanying chemical and physical analyses were consulted. Source map scales varied from 1:20 000 to 1:250 000, while laboratory analyses available ranged from detailed to nonexistent. Polygon boundaries were added (deleted) at this time to account for contrasting (similar) soil properties within map polygons. Information for areas with no soil or terrain maps was extrapolated from adjacent areas and/or estimated based on regional knowledge of the soils of the province.

Based on information for individual map polygons, mapping units with similar characteristics were created. Class limits for the differentiating criteria were established in accordance with the criteria needed to make the desired interpretations. Approximately 100 mapping units resulted from this grouping.

The following map indicates the types of information sources utilized in the preparation of the base map and indicates relative reliability.

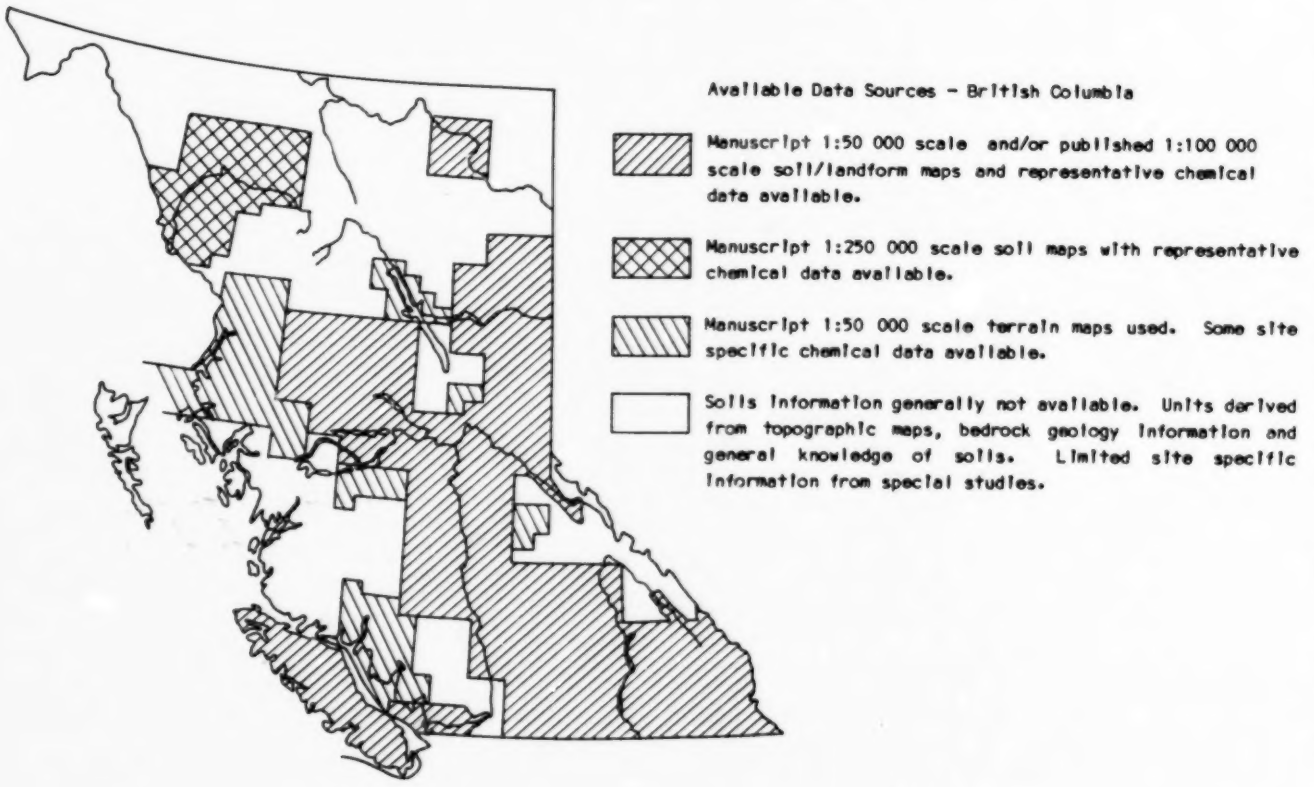
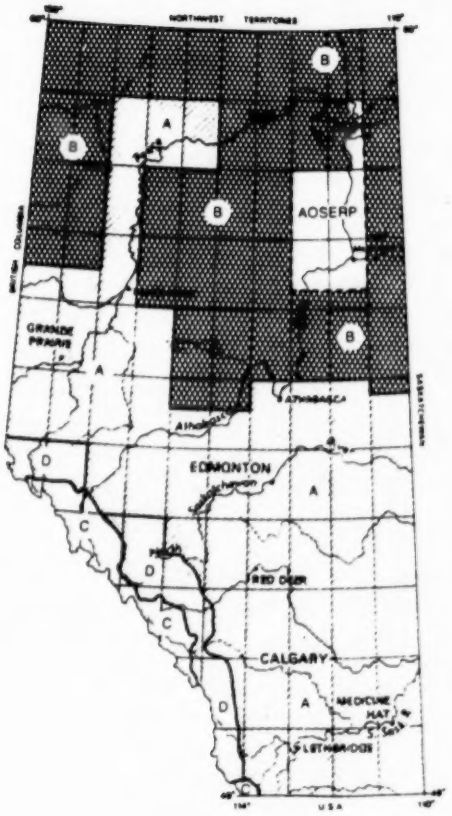

Available Data Sources - British Columbia
Manuscript 1:50 000 scale and/or published 1:100 000 scale soil/landform maps and representative chemical data available.
Manuscript 1:250 000 scale soil maps with representative chemical data available.
Manuscript 1:50 000 scale terrain maps used. Some site specific chemical data available.
Soils information generally not available. Units derived from topographic maps, bedrock geology information and general knowledge of soils. Limited site specific information from special studies.

Figure 2: Available Data Sources - British Columbia

3.1.2 ALBERTA

Information for establishing map units and for characterizing the soils was derived from published or printed sources and from file information. Soil resource

inventories that included taxonomic classification of soils and pertinent data on their properties, served as direct sources. Where such information was lacking or limited in extent, it was inferred from surficial materials, geology, physiography, and/or topography maps, and supplemented by information extrapolated from contiguous or comparable areas that had soil surveys. Figure 3 displays the regions of the province for which different categories of information was available. The soils base map was compiled at a 1:1 000 000 scale.



A Reconnaissance Soil Survey Reports (Agriculture Canada and Alberta Research Council)

B Exploratory Soil Survey Reports (Alberta Research Council)

C Ecological Land Classification (Banff and Jasper National Parks and Soil Survey of Waterton National Park

D Variety of Sources (Physical Land Classification Maps, Alberta Energy and Natural Resources; Surficial Geology Map, Alberta Research Council; Physiographic Map of Alberta)

Figure 3: Soil Inventory Information Source Areas - Alberta

Complete soil survey coverage of region A (Figure 3) was available at scales ranging from 1:50 000 to 1:190 080 and of region C at 1:50 000. Most soil mapping in region A has been to the series level and is supported by field descriptions and laboratory data. Consequently, the soil survey data base for these regions is considered to be very reliable.

With the exception of the AOSERP (Alberta Oil Sands Environment Research Program) area for which there is complete soil survey coverage at 1:126 720, the soils information for region B is only available at 1:750 000. Because of the lower intensity of survey, the map units in region B are larger and are more likely to encompass a greater variety of soils as compared to map units in regions A and C. Although some of the mineral soils in this region have been described, there is almost no information available for the organic soils.

The soil data base for region D is the least reliable. There is no soil survey coverage for much of this region and information about the soils had to be inferred from a variety of different, fairly general sources.

The soils map depicts the areal distribution of various kinds of soils and non-soil materials occurring in the province. Each map polygon encompasses areas in which a certain kind of soil is dominant. Usually, however, other kinds of soils (or non-soil materials) are included in the map polygon, some constituting more than 20 percent of the area.

In such cases, the most extensive of the latter soils are considered to be a subdominant component. Some of the other kinds of soils, although of minor extent, may contribute appreciably to the qualities of the map unit delineations. The characteristics of the dominant and subdominant soils that served as the basis for establishing the map units include taxonomic class, reaction (pH) of surface layer, and for mineral soils the texture and the kind and quality of the parent material or the substrate on which the soils occur.

Full details describing the map unit symbols, the kind of genetic geologic or surficial material of each map unit and the legend may be found in Holowaychuk and Fessenden (1986).

3.1.3 SASKATCHEWAN

To facilitate the development of interpretive ratings, a soil data base was compiled for the province. Soil maps were

used as basis for compilation in the southern region, while in the Shield area to the north, surficial geology maps were used. A triangular-shaped area of about 4 million ha along the Alberta border, south of the Shield and north of latitude 55°N was initially not included because of a lack of soils data. Additional field soil survey work in 1986 served as a basis for the broad delineations included on the interpretive maps in this report.

Soils data that were both related to soil acidification and generally available for the majority of soils in the province were used as diagnostic criteria for mapping units. They included soil texture, soil organic matter, soil reaction, and carbonate content. The bedrock type was also included for areas where the bedrock comprised a significant part of the land surface. The scale of the map showing the extent and distribution of the various mapping units is 1:2 000 000.

The content of exchangeable bases was included in the data base. Since many soils in the province are base saturated, the content of exchangeable bases was assumed to be equivalent to the cation exchange capacity measured at field pH. Cation exchange capacity values measured in the laboratory at pH 8 were adjusted downward according to field pH values. Where measured cation exchange capacity values were unavailable, the cation exchange capacity was estimated using soil texture and organic matter data. The content of exchangeable cations was used as a measure of soil buffering capacity.

The soil inventory data on which the interpretive maps were based vary widely, ranging from detailed reconnaissance surveys throughout most of the settled areas of the province to broad exploratory surveys in the north. In some areas there is no soils information at all. Adequate characterization of some soils is also lacking. Figure 4 illustrates the sources and quality of inventory information available for this project.

3.1.4 MANITOBA

The Environmental Management Division of the Province of Manitoba cooperatively addressed the task of sensitivity mapping in the province with the Canada-Manitoba Soil Survey. Both agencies worked in advisement with the Geological Services Branch, Department of Energy and Mines, Province of Manitoba.

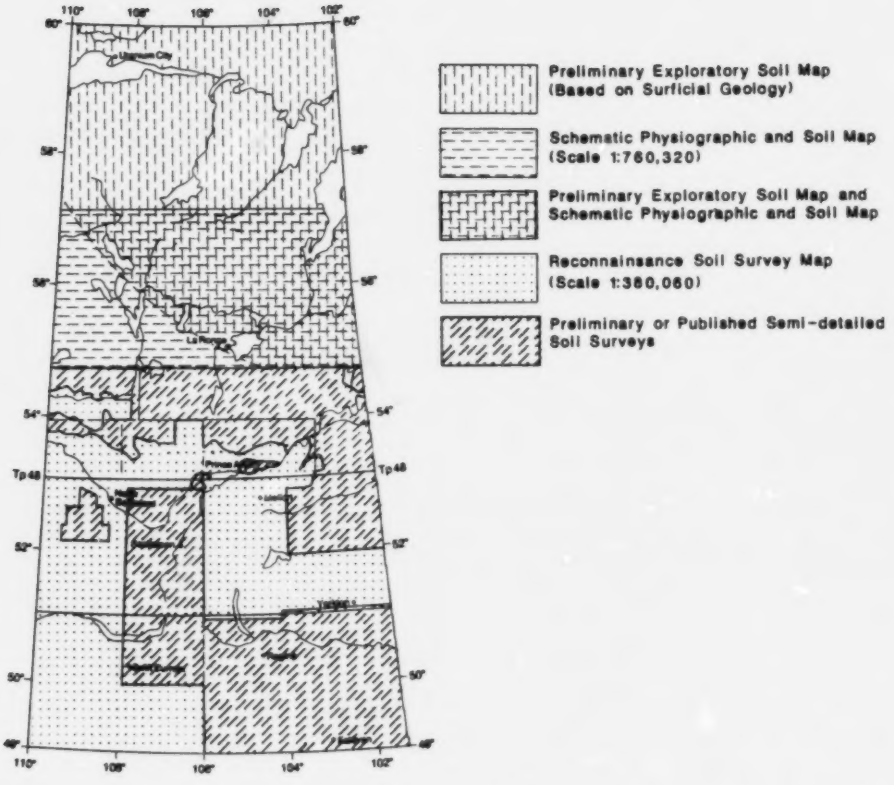


Figure 4: Soil Survey Coverage - Saskatchewan

A generalized soil landscape map (1:2 000 000) and legend provided basic information on dominant and sub-dominant soil and/or bedrock components, texture and carbonate level for map delineations. Soils of similar development, surface texture and carbonate level were grouped into map units. Analytical data for cation exchange capacity, pH and surface texture was summarized for each map unit from published soil survey reports and from soil data files.

Figure 5 portrays regions of the province for which various sources of information were available. It serves as an indication of the reliability.

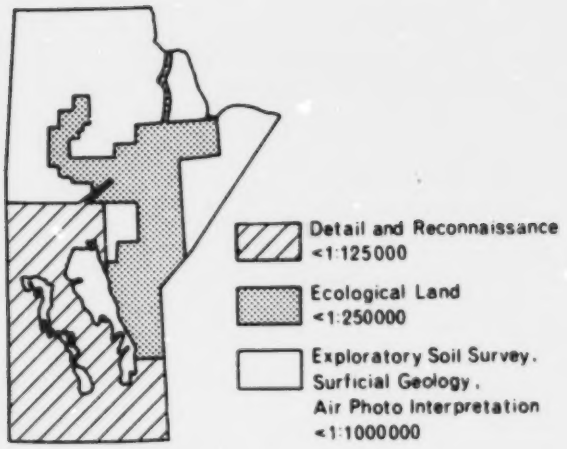


Figure 5: Soil Reliability Map - Manitoba

3.1.5 YUKON TERRITORY

An Ecodistrict map (1:1 000 000) and accompanying database were developed utilizing all available climate, vegetation, bedrock, terrain, Ecological Land Survey and soils information. Landsat color transparencies (1:1 000 000; major portions) and black and white aerial photographs (1:40 000 and 1:70 000; minimal coverage) were used in delineating map polygons. Polygons were characterized by their known or inferred properties in terms of bedrock, genetic materials, relief, depth of materials, broad textural classes and soil taxonomy.

Map polygons were then grouped or split according to similarities or dissimilarities in physical components. Resulting Ecodistrict polygons were more homogeneous but in the process, identification of a number of minor or tertiary components had to be dropped to limit the map unit descriptors to two. This map was then reduced in scale to 1:2 000 000 and became the working base. As a final stage, each "modified" Ecodistrict polygon was described on the basis of known or inferred: bedrock (3 types); genetic materials (8 types); carbonate content of surficial deposits (related to bedrock types); depth of materials (3 classes); texture (5 classes); permafrost (depth); soil taxonomy (Great Group); relief (3 classes); pH; and cation exchange capacity.

Approximately 40% of the land area of Yukon Territory has background information at reconnaissance, or more detailed, levels. The remainder, or about 60%, has exploratory level information and only a scattered number of sites for which more specific detail is available. Figure 6 indicates areas with available background information.

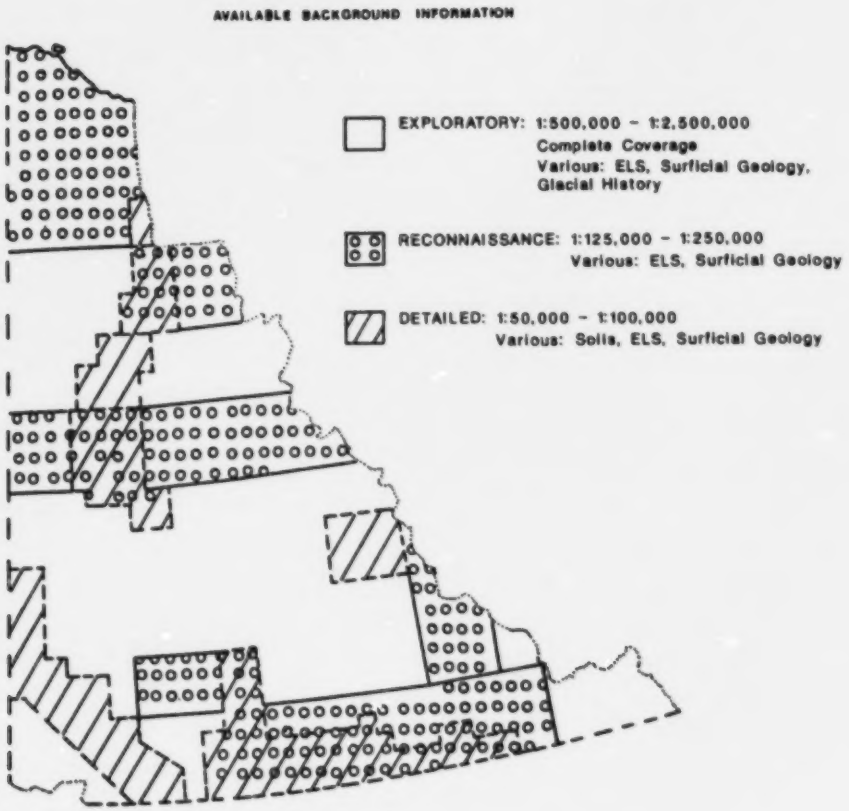

AVAILABLE BACKGROUND INFORMATION
EXPLORATORY: 1:500,000 - 1:2,500,000
Complete Coverage
Various: ELS, Surficial Geology, Glacial History
RECONNAISSANCE: 1:125,000 - 1:250,000
Various: ELS, Surficial Geology
DETAILED: 1:50,000 - 1:100,000
Various: Soils, ELS, Surficial Geology

Figure 6: Available Background Information - Yukon Territory

Detailed soil chemical and physical data are extremely sparse for the entire Territory (approximately 160 sites). With few exceptions these sites are concentrated in the south and confined almost exclusively to low elevation terrain.

3.1.6 NORTHWEST TERRITORIES

Data suitable for a sensitivity assessment of the Northwest Territories are largely derived from small-scale mapping projects and a few detailed and site specific soil or geology reports (scales ca 1:25 000 to 1:125 000). The Ecodistrict Data Base, developed by Environment Canada, provided a framework for the mapping analysis and, when coupled with previously published and unpublished information, provided adequate data for project completion at the mapping scale of 1:5 000 000.

Since 1972, Lands Directorate, Environment Canada, Ottawa, has compiled environmental information and in coordination with their own field surveys, produced an ecological mapping base. The base unit of these maps is the Ecodistrict, an area characterized by distinctive patterns of relief, geology, geomorphology, vegetation, soils, water, and fauna. Ecodistrict maps have been produced through the Northern Land Use Information Series (NLUIS) maps at a scale of 1:250 000 and through the Regional Ecological Land Surveys in the Beaufort Sea, Mackenzie Mountains and the Northwest Passage. Published maps exist for all of the Districts of Mackenzie and Keewatin and about half of the Arctic Islands. Draft Ecodistrict maps at 1:1 000 000 and limited preliminary information were available for most of the remaining Arctic Islands. Interpretation of Landsat imagery was undertaken in a few areas where base information was virtually non-existent.

Geological reports, maps, and soil surveys were consulted and cross-checked with the information contained in the Ecodistrict Data Base during the data compilation phase of the project. This was done to ensure data compatability and comparability for all areas. Researchers from Environment Canada, Agriculture Canada Research Branch, Canadian Forestry Service and Geological Survey of Canada reviewed the map for content and accuracy.

Ecodistricts were used to define the basic mapping polygons. Where Ecodistricts did not appear to reflect the diversity in bedrock and soils identified by the data, new units were constructed.

Each map unit was coded according to soil texture, soil depth, mode of origin and bedrock type. Any inconsistencies between or within data sources were identified and resolved at this level. Where more than one combination of the variables was found in a single polygon, compound units were created. These identified the percent coverage for each of the two dominant combinations. The secondary combination had

to cover at least 20% of the map polygon in order to be included in the analysis.

Individual map units were then combined where two or more polygons were coded similarly and shared a common boundary. These new composite polygons were delineated at 1:1 000 000.

The following reliability index map illustrates the relative reliability of the sensitivity assessment based on the scale and quantity of available data sources. Interpretations for areas for which published Northern Land Use Information Series maps were evaluated in conjunction with Geological Survey of Canada (GSC) and soil survey reports are believed to be the most reliable.

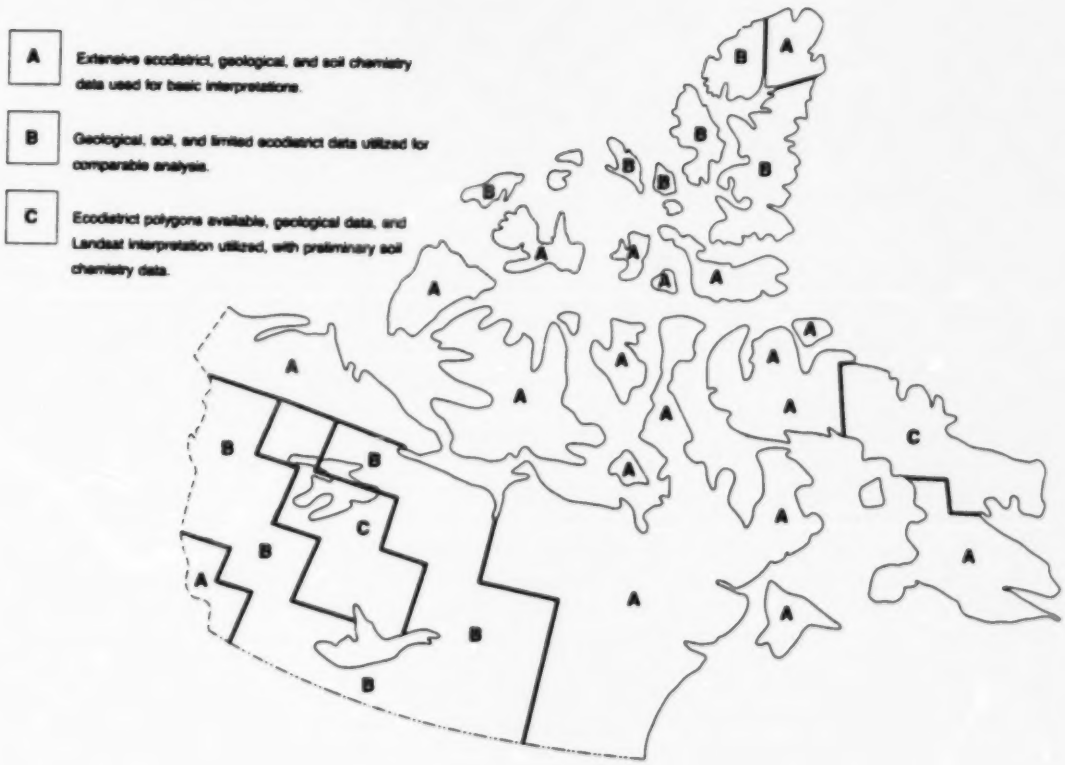

A
Extensive ecodistrict, geological, and soil chemistry data used for basic interpretations.
B
Geological, soil, and limited ecodistrict data utilized for comparable analysis.
C
Ecodistrict polygons available, geological data, and Landsat interpretation utilized, with preliminary soil chemistry data.

Figure 7: Reliability Index - Northwest Territories

3.2 POTENTIAL OF SOILS AND GEOLOGY TO REDUCE ACIDITY OF ATMOSPHERIC DEPOSITION

Rating of mapping units was done generally according to criteria and procedures developed in Eastern Canada (Cowell et al., 1981; Lucas and Cowell, 1984), as described in section 2.4.1. These procedures were adopted as guidelines for Western Canada (Wiens, 1982, 1983); however, variations in source of data as described above, resulted in certain assumptions and procedures unique to each province or territory. These are highlighted below.

3.2.1 BRITISH COLUMBIA

Mapping units of the base soils and geology map were rated according to bedrock, bedrock and soil, or soil characteristics alone (Figure 1). It should be noted that in B.C. all mapping units dominated by one of four classes of bedrock (limestone or dolomite) were immediately rated as high. In some cases, though soils may be deep or are underlain by compact glacial till with little resulting opportunity for direct rainwater contact with bedrock, and though the soils might otherwise be rated as moderate or even low, the final rating appearing on the map is high. Areas dominated by exposed bedrock were rated according to bedrock sensitivity ratings generally as proposed by Shilts et al. (1981), with adjustments as appropriate for available B.C. bedrock geology data. Mapping units dominated by organic terrain, though indicated in the rating procedure to be low (Figure 1), were evaluated further before rating. As for mineral soils, data on sum of exchangeable bases was assessed if available. If values when corrected for mass per unit volume were in the range for a rating other than low, the revised rating was assigned.

Mapping units dominated by mineral soils were evaluated as indicated in Figure 1, with criteria as in Table 1. Because the sum of exchangeable bases was available or inferred for all mapping units, surrogate properties were not required.

Areas dominated by ice or glaciers were not rated. These areas were simply noted as such on the map.

Once mapping units had been evaluated based on soil and geology characteristics, ratings were portrayed in colour on the 1:2 000 000 scale maps. Where a map polygon involved a combination of two mapping units, the rating of the dominant mapping unit only was portrayed. Whereas the 1:2 000 000 B.C. soils map portrayed four rating classes (low, moderate-low, moderate-high, high) the middle two classes were combined for the accompanying 1:7 500 000 Western Canada map.

3.2.2 ALBERTA

The rating of map units dominated by mineral materials was based on combinations of soil depth, exchangeable base concentration, bedrock type, parent or surficial material type, and drainage class as per the guidelines and criteria that were developed in Eastern Canada and that were adopted by the western participants (Wiens, 1983). In Alberta, additional criteria were developed to rate map units dominated by Organic and Organic Cryosol soils.

Organic and Organic Cryosol soils are considered to be peatland systems consisting of an organic matrix-ambient water system, and defined on the basis of their pH and base cation concentration. Eutrophic peatland systems have a high pH and a relatively high concentration of base cations reflecting a sustained influx of base-charged minerotrophic waters. The acidity neutralizing potential of this system is postulated to be high. Mesotrophic systems are of intermediate reaction (pH) and base cation concentration in the surface layer, but become less acid with depth. It is expected that incident acidity will acidify the surface layer water but that the effluent will be moderated to a varying degree by influx from the lower layers to contribute to a medium potential to reduce the acidity. The surface layer waters of Oligotrophic-ombrotrophic systems are extremely to strongly acid. A low potential to reduce acidity is predicted for these systems.

3.2.3 SASKATCHEWAN

It is recognized that the water quality in most lakes is closely related to the substrates through which the percolating waters have moved. It follows, therefore, that the relative sensitivity of a particular lake or aquatic system is dependent, at least in part, upon the nature and characteristics of the surrounding terrain.

The ability of a soil to neutralize acidity, often referred to as its buffering capacity (BFC), is ultimately governed by the content of bases in the soil which, in turn, is related to the presence of carbonates and to the content of exchangeable bases. Since data concerning the latter were not available for most soils in the province, the cation exchange capacity and the pH of the soil were used to estimate it.

For mineral soils, the ratings were based on the entire depth of the control section (2 m), although consideration was also given to the properties of the underlying substrate in some cases. In organic soils, the buffering capacity was

estimated on a volume rather than a weight basis because of the low bulk density of these soils and the very high CEC if it is expressed on a weight basis. When expressed on a volume basis, the BFC of most organic soils is comparable to that of mineral soils.

Bedrock types, which outcrop mainly in the Shield area of the province, were classified using the system described by Shilts et al. (1981).

3.2.4 MANITOBA

Three classes (low, moderate, and high) for soils and two classes (low or high) for bedrock where used for rating potential of soils and geology to reduce acidity of atmospheric deposition. The criteria provided in Table 1 were used. In areas with two ratings, the first rating is considered to account for 50% or more of the area, and the second at least 20%. Only the dominant rating is portrayed on the Western and Northern Canada map, however. The influence of soil and bedrock to a depth of 2 meters was used to assign areas into classes.

A low rating for potential to reduce acidity was assigned to soils that are generally acidic (pH<5), coarse textured (sand, loam/sand, sandy loam) and have a low cation exchange capacity (~8meq/100g). Organic (bog) soils were included in this class because of their acid nature and low base status. Map units dominated by acid bedrock were also assigned a low rating for potential to reduce acidity.

A moderate rating was assigned to areas with soils that are slightly acidic and contain a moderate amount of exchangeable bases. Organic soils, many of which extend beyond the control section of 2 meters, were rated as moderate.

Inorganic materials underlying organic soils may have a high capacity to reduce acidity and this condition has been noted. Clay textured Luvisolic soils, associated with Organic soils in Northern Manitoba, were assigned a moderate rating. It was assumed that rapid downward movement of soil water would be restricted by the compact clay and that lateral flow through the non-carbonated upper zone may be a significant factor in water movement to lakes and streams.

A high potential to reduce acidity rating was assigned to soils high in exchangeable bases and with carbonates present in the subsurface. Bedrock containing limestone, dolomite and other carbonate bearing rocks was also rated as having a high potential to reduce acidity.

3.2.5 YUKON TERRITORY

Utilizing the soils and geology maps and data base, interpretation of the buffering capacity of the various map unit components was carried out (i.e., soils, surficial and bedrock geology). Methods and criteria were adapted from Cowell et al. (1981).

Three classes of bedrock were recognized:

1. carbonate bearing rock: limestone, dolomite etc.

2. non-carbonate bearing fine to medium-grained rock: basalts, sandstone, shale, etc.

3. non-carbonate bearing coarse-grained rock: granite, granodiorite, gneiss, etc.

In the unglaciated portions of Yukon Territory, the carbonate content of surficial materials and chemistry of the weathered surface materials is directly related to the underlying bedrock. An exception exists where loess deposits are deep.

Where permafrost is widespread or continuous (north of about 64°N), subsurface deposits and underlying bedrock are often out of reach of downward moving water. Under these circumstances, only the material above the permafrost table was considered in the interpretations.

The following potential to reduce classes and characteristics were identified:

Low Potential

- shallow and/or deep, low carbonate bearing materials over coarse to medium-grained bedrock

- low to moderate carbonate bearing materials with shallow permafrost table

- barren areas with coarse-grained and medium to coarse-grained bedrock

Moderate Potential

- shallow and/or deep, moderate carbonate bearing materials over medium-grained bedrock

- shallow, high carbonate bearing materials over coarse to medium-grained bedrock

- moderate to high carbonate bearing materials with shallow permafrost table
- barren areas with medium-grained and medium to fine-grained mixed bedrock types

High Potential

- deep, high carbonate bearing materials over the complete range of bedrock types
- shallow, high carbonate bearing materials over fine-grained bedrock (limestone, dolomite)
- barren areas with fine-grained bedrock, (limestone, dolomite)

Permanent ice and snowfields are delineated as such and were not classified.

Extensive areas of organic deposits, large enough to be shown at the scale of mapping used, are rare and exist only in the north where permafrost is present at shallow depth. Their potential to reduce acidity is considered to be low.

Once the potential to reduce acidity ratings were depicted on the 1:2 000 000 soils and geology map, units with a similar rating were grouped together. This map was reduced to 1:5 000 000 and further modified to accommodate scale change.

Specific chemical and physical data on soils and surficial materials are extremely sparse. Large data gaps exist most often related to mountainous terrain and higher latitudes. Although inferences drawn from complete bedrock and glacial history maps were used to fill these gaps, little ground-truthed data was available to confirm the interpretations.

3.2.6 NORTHWEST TERRITORIES

Map units were identified as having high, moderate or low potential to reduce acidity of atmospheric deposition.

Lucas and Cowell (1984) identified three criteria as being significant for the delineation of sensitive areas: soil depth, soil chemistry (soil carbonate content was used in this analysis) and bedrock type. These factors were combined in individual terrain units to derive the sensitivity ratings.

The sensitivity of permanent icefields/glaciers and areas containing extensive organic deposits were not assessed but rather delineated onto the map.

Map polygons were described by their assigned sensitivity rating and the specific combination of soil and bedrock attributes contained within that polygon. Compound polygons were created where more than one combination of the variables were found in the same unit. The secondary combination had to cover at least 20% of the map polygon to be included in the analysis.

Unique to northern environments is the presence of permafrost. Allowances for the presence of permafrost have been made in the interpretation. It was assumed that soil permafrost forms an impermeable barrier to the vertical movement of water and was interpreted as a reduced influence of bedrock in terrains with shallow surficial deposits. To avoid confusion, the interpretations of potential to reduce acidity reflect the presumed presence of permafrost throughout the Northwest Territories. The sensitivity rating may be adjusted for map units occurring within discontinuous permafrost areas, where the absence of permafrost is thought to significantly alter the buffering effect, by referring to the map legend.

The assessment reflects the general terrain characteristics and their presumed influence on surface water chemistry. The classes identified are regional evaluations and are not meant to be interpreted for individual or specific sites. No attempt should be made to derive larger scale maps from this product without consultation of the individual data sources.

3.3 SOIL SENSITIVITY TO ACIDIC INPUTS

Background, definitions, and rating criteria have been discussed in section 2.0 above. In addition to rating expected responses of soils to the three processes of soil acidification, exchangeable base cation loss, and aluminum solubilization, a composite rating was given (Table 2). This composite rating was portrayed on maps and generalized for this report. Such maps were prepared for each of the provinces and the Yukon Territory, but not the Northwest Territories where insufficient data was available.

Though rating criteria were accepted by all provinces and territories, differences in available data caused some variations in application. Unique characteristics of organic soils in particular, combined with minimal inventory

information has resulted in the greatest variations in rating and mapping of these areas. The following sections highlight aspects of mapping in each of the provinces and territories.

3.3.1 BRITISH COLUMBIA

Mapping units were rated for sensitivity to acidic inputs according to agreed on criteria (Table 2). In developing the ratings, adjustments were made in cation exchange capacity values for Organic soils or soils high in organic matter, based on their estimated lower mass per unit volume. Even so, data sources for these areas were sparse. All ratings portrayed assume soils are non-sulphate adsorbing. According to agreements on procedures, ratings were based on characteristics of the top 20 centimetres of soil. In some areas of known, very shallow soils (e.g. 10cm), the assigned ratings are one sensitivity class higher to reflect the very limited depth of soil available for buffering.

Ratings are depicted for dominant components of map polygons only. In a few cases where a subdominant component is a significant part of the unit and its sensitivity rating is significantly different, an adjustment of the rating of the entire map polygon was made (e.g. a higher sensitivity was portrayed). Available site specific information would normally be the basis for such adjustments. They were few in number.

3.3.2 ALBERTA

Map units dominated by mineral soils were rated according to the criteria developed by the western participants. Although no criteria were developed for Organic soils, because large areas in the northern half of Alberta are occupied by Organic or Organic Cryosol soils, a provisional attempt was made to evaluate their sensitivity to acidic inputs. The approach taken was to categorize Organic and Organic Cryosol soils into three peatland systems based on the chemical properties of the organic materials and their associated ambient water.

The Eutrophic system is characterized by both organic matrix materials and associated surface waters with significant concentrations of exchangeable bases, high base saturation and neutral to mildly alkaline reaction. These conditions indicate that this system will be able to sustain a high level of bicarbonate buffering and that acidification and relative base loss will be minimal. Because of the high pH, aluminum solubilization is also expected to be negligible. The sensitivity of all processes is rated as low, as is the overall sensitivity.

The base cation content of the ambient water in the Mesotrophic system ranges from moderately low to moderately high. Indicated bicarbonate contents are moderately high to moderately low as is buffering capacity. The pH ranges from 5.0 to about 6.5. Base saturation of the organic matrix surface layer ranges from very low to medium. Mesotrophic systems in Alberta are rated as highly sensitve to base loss and acidification. Sensitivity to aluminum solubilization is rated as medium. Overall the sensitivity of Mesotrophic systems to acid deposition is considered to be high.

The Oligotrophic peatland system, which also includes the Ombrotrophic peatland, is extremely to very strongly or strongly acid with very low contents of base cations in the ambient water. The base saturation of the organic component is very low to moderate. The very low base cation content of surface water indicates that there is very little or no bicarbonate buffering. Rather, these systems are buffered in the extremely acid to very strongly acid range by aluminum and humic acid systems as discussed by Johannessen (1980). Additions of acid will cause little if any change in pH. Several active processes discussed in the literature (Clymo, 1984; Braekke, 1981; Damman, 1978) led to the assumption that sensitivity to base loss is also low in these systems. Sensitivity to aluminum solubilization will be high due to the extremely acid condition if sources of aluminum are available such as mineral dust or associated mineral soil or rock materials. The overall sensitivity to acid deposition is considered to be low.

The sensitivity ratings assigned to map units dominated by Organic and Organic Cryosol soils should be considered provisional. While considerable attention has been devoted to establishing criteria for mineral soils, very little research has been done regarding the sensitivity of Organic soils or peatland ecosystems (Gorham et al., 1984). Furthermore, the majority of map units dominated by Organic or Organic Cryosol soils are in region B (Figure 3), a region for which the soil survey data base is very general at best. For many of the map units in this region there were no available data on the chemical properties of the Organic soils or the associated waters.

3.3.3 SASKATCHEWAN

Interpretations are based largely on two sensitivity-pertinent soil properties: cation exchange capacity and pH. Initially, the soils were rated in terms of their sensitivity to base cation loss, to soil acidification (pH change), and to aluminum solubilization. The final overall

sensitivity rating was derived from the three initial ratings (Table 2). The ratings are based on the surface 20 cm of soil.

Soils rated high are mainly Brunisolic soils developed on coarse-textured glacial till and glaciofluvial deposits in the Shield area of the province. They are generally very acidic and have a low CEC and are thus considered sensitive both in terms of base cation loss and aluminum solubilization. Extremely acidic sphagnum-dominated Organic soils also occur in this category. Most coarse-textured soils in the Boreal Forest region and a few in the Prairie region are also considered highly sensitive.

Soils in the moderate category are generally slightly to strongly acidic, have a moderate to high CEC and, for the most part, are considered moderately sensitive in terms of both base cation loss and aluminum solubilization. They include Luvisolic soils developed on glaciolacustrine clays in the southeast corner of the Shield, Luvisolic soils developed on relatively low lime glacial till deposits throughout the Boreal Forest region, Solonetzic soils located mainly in the extreme southern part of the Province, and some medium to strongly acid Chernozemic soils found mainly in west-central Saskatchewan.

Soils in the low category comprize the bulk of the southern agricultural region of the province. Most are classified in the Chernozemic order and have developed on medium- to fine- textured deposits. The soils are slightly acid to alkaline in reaction, have a high CEC and are thus considered relatively insensitive not only in terms of their overall sensitivity but in terms of all three component processes as well.

3.3.4 MANITOBA

Soil sensitivity classes (low, moderate and high) were a synthesis of the ratings for individual factors as outlined in Table 2. In applying the criteria to rate map units several considerations were important. Firstly the soil properties of the surface 20 cm were most important in application of the criteria. Secondly, whenever dominant and subdominant soil and/or bedrock components exhibited similar properties a single class rating was assigned. Thirdly, two class ratings where assigned to some mapping units and indicate a condition where dominant and subdominant components had different soil properties. The first class accounted for 50% or more of the soils and the second class at least 20%. (For this report and map, however, the ratings for only the dominant class are presented.) Finally, Cryosolic soils were rated based on soil pH and cation

exchange capacity properties. The cryogenic condition of the soil was not incorporated into the sensitivity rating.

In general, the low sensitivity class was comprised of soils with a cation exchange capacity greater than 15 meq/100g, high exchangeable base content, and pH values greater than 6.0. Soils with carbonates present to the surface and carbonate bearing bedrock were assigned to the low sensitivity class.

Soils rated as moderately sensitive have cation exchange capacities of 6 to 15 meq/100g, moderately high exchangeable base content, and pH values in the range of 4.6 to 6.0. Surface textures of soils are usually sand, loamy sand and sandy loam, and carbonates are present in the subsurface. Some finer textured soils with leached surface conditions and usually associated with Organic soils were placed in the moderate class. Organic (fen) soils were also placed in the moderate class.

The high sensitivity class contained soils that are acid in nature, and have textures of sand, loamy sand and sandy loam. Many of these soils are associated with organic soils and acidic bedrock. Measured chemical data indicate an average cation exchange capacity value of 8 meq/100g and an average pH value of 4.5.

3.3.5 YUKON TERRITORY

Utilizing the modified Ecodistrict data base, the soils (upper 30 cm) were assessed in terms of their sensitivity to three processes: soil acidification, base cation loss, and aluminum solubilization. A combined, single rating was arrived at from each of the three processes for any particular soil.

In constructing the original data base, available site specific chemical data, in particular pH and CEC, were extrapolated over entire map units where applicable. Where data was not available, these parameters were inferred from parent material, texture and soil taxonomy.

In general, most sensitive soils are extremely acid to medium acid and have a low cation exchange capacity (pH 4.5 or less to about 5.5, and a CEC most often less than 10 meq/100g but occasionally up to 15 meq/100g).

Soils rated as moderately sensitive are generally very strongly to slightly acid with intermediate cation exchange capacity (pH 5.0 to 6.5 and a CEC from 10 meq/100g to about 25 meq/100g).

Least sensitive soils are generally slightly acid to alkaline and have a high cation exchange capacity (pH > 6.0 and a CEC generally greater than 25 meq/100g). An area of terrain, largely permanent ice and snowfields, remains unclassified.

Available site specific and regional data are insufficient to reliably interpret sensitivity without relying on inference. Most of the site specific data are concentrated in the south and generally associated with lower elevations. The effects on sensitivity rating of a shallow permafrost table and relatively short thaw periods, conditions present across the northern half of Yukon Territory, are unclear.

3.3.6 NORTHWEST TERRITORIES

No attempt was made to interpret the sensitivity of soils of the Northwest Territories based upon site specific soil and surficial material chemical data. It was felt that, without abundant data, the potential variation in soil chemistry over even short distances would reduce the value of any attempted interpretation. Additional site specific and regional soil and surficial material chemical data are required before attempting to interpret the sensitivity of northern soils to acidic inputs.

4. GENERAL OBSERVATIONS ON SENSITIVITY MAPS

4.1 BRITISH COLUMBIA

A large area of mainland coastal B.C. and of Vancouver Island has been assigned a low rating for potential to reduce acidity. These areas are dominated by shallow acid soils and/or acidic type bedrock (e.g. granite, syenite). Central and northern parts of the province and areas of the Kootenays are similarly rated low. High potential is indicated for a portion of the Rocky Mountain area underlain by calcareous bedrock, the eastern Kootenays, and the northern extension of the Rocky Mountains and Foothills. This high potential area extends into the dry central interior dominated by neutral to alkaline soils, and the fine textured, old lake basin around Prince George. A further area of the Cariboo and Thompson plateaus is indicated as having high potential, also due primarily to alkaline soils. Moderate ratings are indicated for considerable portions of the interior of the province. The very small scale, highly generalized nature of this map and the major inclusions which exist within each area must be emphasized. These inclusions are displayed only on the larger scale source maps.

Vancouver Island, the Queen Charlotte Islands, the Coastal Mountains, the Monashee and Purcell Mountains, as well as large portions of Northern B.C. are rated as highly sensitive to acidic inputs. Low sensitivity is indicated in the fine textured old lake basin in the Prince George area, and in the more alkaline soil areas of the Cariboo and Thompson plateaus. Notable areas rated as moderate are in the eastern Kootenays and Rocky Mountains, and in Northern B.C.

4.2 ALBERTA

Ratings of low, moderate, and high potential to reduce acidity were given to roughly 11, 22, and 64 percent respectively, of the total land area of the province. Ratings of high, moderate, and low soil sensitivity to acidic inputs were given to roughly 23, 31, and 44 percent respectively, of the total land area of the province.

Major areas of soils and geological materials with low potential to reduce and high sensitivity of soils are in the northern and Northeastern portion of the province. Granite and granite type rocks and associated extremely, to very strongly acid sandy Dystric Brunisol soils prevail in this Shield area of Northeastern Alberta. Acid reducing potential here is low and soil sensitivity is high. Additionally, soils in areas of non-carbonate rocks in the mountains were

assigned a high sensitivity rating. Organic and Organic Cryosol soils classified as Oligotrophic peatlands occurring in Northern Alberta were rated as having a low potential to reduce acidity. Mesotrophic peatlands located in the northern and northeastern portions of the province were assigned high soil sensitivity ratings. Remaining areas of highly sensitive soils are scattered throughout the province.

Areas rated as having moderate potential to reduce acidity are dominantly the Mesotrophic peatlands, primarily in Eastern Alberta (north of 55°). Mineral soil areas rated moderate occur in the Rocky Mountains (non-calcareous clastic sedimentary rocks and rock areas), Foothills region (where bedrock derived materials have contributed appreciably to the surficial materials), and Plains region (localized occurrences of low base content sandy materials).

The major groups of soils placed in the moderate sensitivity category are the Orthic Gray Luvisols and the Brunisolic and Podzolic Gray Luvisols. These soils have very extensive distribution in the central and eastern slopes regions of the province and taken together comprise almost one-quarter of the area of the province. There are also large areas of Solonetz and Solonetzic Gray Luvisol soils that are classed as being of medium sensitivity.

A very large portion of the Plains region, with the exception of the area covered by some Organic and Organic Cryosol map units, is rated as having a high potential to reduce acidity. Additionally, this rating was assigned to areas in the Rocky Mountains (carbonate rock and rock materials and related soils derived from calcareous materials), and in the Foothills regions (south of the Bow River where glacial deposits are more consistently calcareous).

Soils of the Chernozemic Order, the most productive agricultural soils in the southern and central regions of the province, and the Black and Dark Gray Solod soils in the Peace River area, are primarily rated as being of low sensitivity. Eutrophic and Oligotrophic peatland soils across the north of the province were also placed in this category of low sensitivity.

4.3 SASKATCHEWAN

The two accompanying maps, show that the potential impact of acidic deposition on Saskatchewan's land resources is substantial throughout the northern regions, and

particularly in the Shield area. In the southern agricultural region it is, for the most part, negligible.

Areas with low potential to reduce acidity and high soil sensitivity are mainly sandy, extremely to very strongly acidic, carbonate free, low buffering capacity soils developed on coarse textured glacial deposits. Almost the entire Shield area of the province consists of these soils. Additional sandy areas of the Boreal Forest Region south of the Shield are similarly rated. Extensive tracts of highly acidic, sphagnum-dominated Organic soils in the Boreal Forest Region are also rated as having low potential to reduce, and highly sensitive soils.

Moderate ratings for potential to reduce were given to Gray Luvisol soils in the Boreal Forest Region, and sandy Regosolic and weakly developed Chernozemic soils occurring sporadically throughout the Boreal Forest and Prarie Regions.

Moderate ratings for soil sensitivity were given to Luvisolic soils in the southeast corner of the Shield, areas of low-lime glacial till throughout the Boreal Forest Region, Solonetzic soils in the extreme southern part of the province, and some medium to strongly acid Chernozemic soils found mainly in West Central Saskatchewan.

The largest part of the southern agricultural region of the province, an area dominated by Chernozemic or Solonetzic soils developed on medium- to fine-textured deposits, was assigned a high potential to reduce, and a low soil sensitivity rating. High buffering capacities characterize the soils and carbonates usually occur within a metre or so of the surface. In addition to these soil areas, large tracts of sedge-dominated Organic soils, primarily in the Boreal Forest Region, were also assigned a high rating for potential to reduce acidity.

4.4 MANITOBA

Soils and bedrock rated as having a low potential to reduce acidity correspond to soils rated as having a high sensitivity to acidic deposition resulting from the long-range transport of air pollutants. In Manitoba, such areas are found on the east side of Lake Winnipeg and in the northwest corner of the province.

Soils in the highly sensitive class are sandy, low in organic matter, very strongly to slightly acidic and generally associated with Precambrian bedrock. These soils have a low content of exchangeable bases (<6 meq/100g) and a

low buffering capacity. Two areas of high sensitivity were identified: an area east of Lake Winnipeg and an area in the northwest corner of the province.

Areas rated as having a moderate potential to reduce acidity are dominantly comprised of Organic soils. Areas classified as moderate are found adjacent to and north of Lake Winnipeg as well as in the northeastern area of the province.

Soils in the moderate class are slightly to strongly acidic, have a moderate base content (6-15 meq/100g) and a moderate buffering capacity. Areas of moderate sensitivity are generally composed of acid Organic soils in the northern area of Manitoba and in the area adjacent to Lake Winnipeg. In the agricultural region of the province, coarse textured (sand, loamy sand), well drained soils and soils with strong evidence of surface leaching were rated as moderate-low in sensitivity.

Soils containing carbonates, and/or limestone bedrock areas are rated as having a high potential to reduce acidity and therefore a low sensitivity to incoming acidic compounds. In Manitoba the southern and southwestern region of the province is found to have a high potential to reduce acidity or low sensitivity soil sensitivity.

Soils in the low sensitivity or non-sensitive class in the rating of soil sensitivity to acidic inputs are soils generally high in clay and/or organic matter. These soils have a high buffering capacity and a high content of exchangeable bases (>15 meq/100g). Some soils are calcareous. The soils of the southern, interlake and western regions of Manitoba were found to be predominantly non-sensitive.

4.5 YUKON TERRITORY

Terrain rated as having low potential to reduce acidity occurs in the far north, along the eastern border, in the south centre and in the west. (Acidic bedrock, shallow soils and shallow permafrost table are the main characteristics of this category.) Moderate potential terrain occurs in the south centre and northeast.

High potential terrain, commonly associated with limestone and/or dolomite bedrock occurs in the southeast, northeast and north centre, and along the eastern border.

Soils with high sensitivity to acidic inputs occur in the north along the eastern border, in the south centre and

southeast. Moderate sensitivity soils occur in a southeast-northwest band in the south. Low sensitivity soils occur sporadically throughout the southern area but are only mappable at this scale in the southwest. Ranges in pH and CEC (known or inferred) were used to differentiate between classes.

4.6 NORTHWEST TERRITORIES

Terrain in the Shield area, Melville Peninsula and Baffin Island was determined to be highly sensitive to acidic deposition. The soils are mostly shallow and have low or moderate carbonate content along with the underlying bedrock. Although some areas with deep soil have underlying bedrock containing calcareous material, most drainage waters will not reach the soil/bedrock interface because of permafrost, and thus, the bedrock has little buffering effect.

Terrain in the northern and central MacKenzie and Franklin Mountains has moderate sensitivity to acidic deposition. Soil carbonate content is generally moderate to high which gives these soils a moderate buffering potential.

The high arctic islands, including Victoria Island, Ellesmere Island and Northern Baffin Island, generally have low or moderate sensitivity to acidic inputs.

5. LIMITATIONS TO MAP USE

Preparation of maps within each jurisdiction has allowed good access to source data. Data base refinements were often possible through direct consultation with inventory personnel during the project. In addition, greater familiarity with resources under management control of each jurisdiction has been achieved. This should assist future monitoring and development of relevant control measures.

There are limitations, however, to use of the maps from this project. These should be recognized when the maps are used. These limitations are highlighted briefly below.

5.1 BOUNDARIES

Base and sensitivity maps were prepared within each jurisdiction (except for the Yukon and Northwest Territories whose mapping was done by Federal agencies). Prior agreements on rating criteria and mapping methods, as well as ongoing discussions between participants were the means used to achieve consistency. Several border matching problems remain between jurisdictions, however. Though they have been resolved by compromise for small scale maps accompanying this report, full resolution awaits collection of further inventory information or research relating to the rating criteria.

5.2 DATA BASE LIMITATIONS

Maps for each jurisdiction (section 3.1) and an inset on the enclosed maps, generally identify available data sources. More complete mapping coverage, more detailed mapping, more representative supporting laboratory analyses, and more data specifically for characteristics used to rate sensitivity, were recognized as desirable for each province and territory. Nevertheless, at the small scale of map compilation used in this project many inclusions in map polygons are hidden for areas where detailed information was available.

No new field data collection could be undertaken in support of this project. (An exception is the three weeks of field time used by Saskatchewan to review about 4 million hectares along the Alberta border, south of the Shield and north of 55°N.) Existing data sources were used. Inventory data, survey intensities and map scales, supporting laboratory analyses etc. have varied widely. Many inferences were required to derive data needed for sensitivity interpretations (e.g. cation exchange capacity from soil texture; soil texture from bedrock geology). Uncertainties inherent in this process were therefore carried through

to the sensitivity rating stage, and variations among provinces and territories may be reflected.

5.3 MAP GENERALIZATION

The 1:7 500 000 scale maps accompanying this report were generalized from the 1:2 000 000 maps submitted for provinces and the 1:5 000 000 maps for territories. Small areas portrayed at these larger scales may have been deleted. Map polygon boundaries have also been simplified in the process. As well, several incompatibilities at jurisdictional boundaries have been reconciled. Accompanying maps therefore reflect several compromises.

5.4 RATING CRITERIA

Criteria adopted for rating the potential of soils and geology to reduce acidity of atmospheric deposition were largely those developed in Eastern Canada under the M.O.I. process. Certain assumptions were questioned (e.g. contact of precipitation derived drainage waters with underlying bedrock in areas of occurrence of impervious layers such as compact glacial till of permafrost) and rating adjustments made where deemed appropriate or required due to missing data. It is acknowledged that a much better understanding is required, of the pathways of precipitation drainage waters before entry into surface waters, and of the chemical changes and watershed processes occurring. Though rating assignments for organic terrain were made by adjustment of soil properties based on mass per unit volume, and by use of alternate sensitivity concepts and criteria in Alberta, prediction of response of organic terrain areas to acidic inputs urgently requires further research.

Ratings of soil sensitivity to acidic inputs, the interpretation intended to reflect responses of soils as they would affect plant growth, must be considered provisional. Future improvements can undoubtedly be made. Though soil acidification, base cation loss, and aluminum solubilization were selected as important component processes in rating sensitivity, details of changes in these processes with acidic inputs and of the relative importance of each to plant growth and overall sensitivity rating require considerable research. Other soil processes (e.g. trace element dissolution, nitrification, organic matter mineralization) may be affected as well. Their relative importance has not been determined. Furthermore, effects of varying soil characteristics such as sulphate adsorption capacity, and contents of various buffering agents are not fully understood.

5.5 SUMMARY ON LIMITATIONS

The maps accompanying this report provide an overview of likely response of Western and Northern Canada soils and geologic materials to acidic inputs. Interpretations have been made regarding potential effects on water and vegetation. Use of them should recognize their limitations, however. Site specific conclusions should not be attempted by using them. For this purpose maps prepared for each province and territory should be consulted, and interpretations discussed with appropriate management agencies.

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MAPS NOT

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CARTES

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